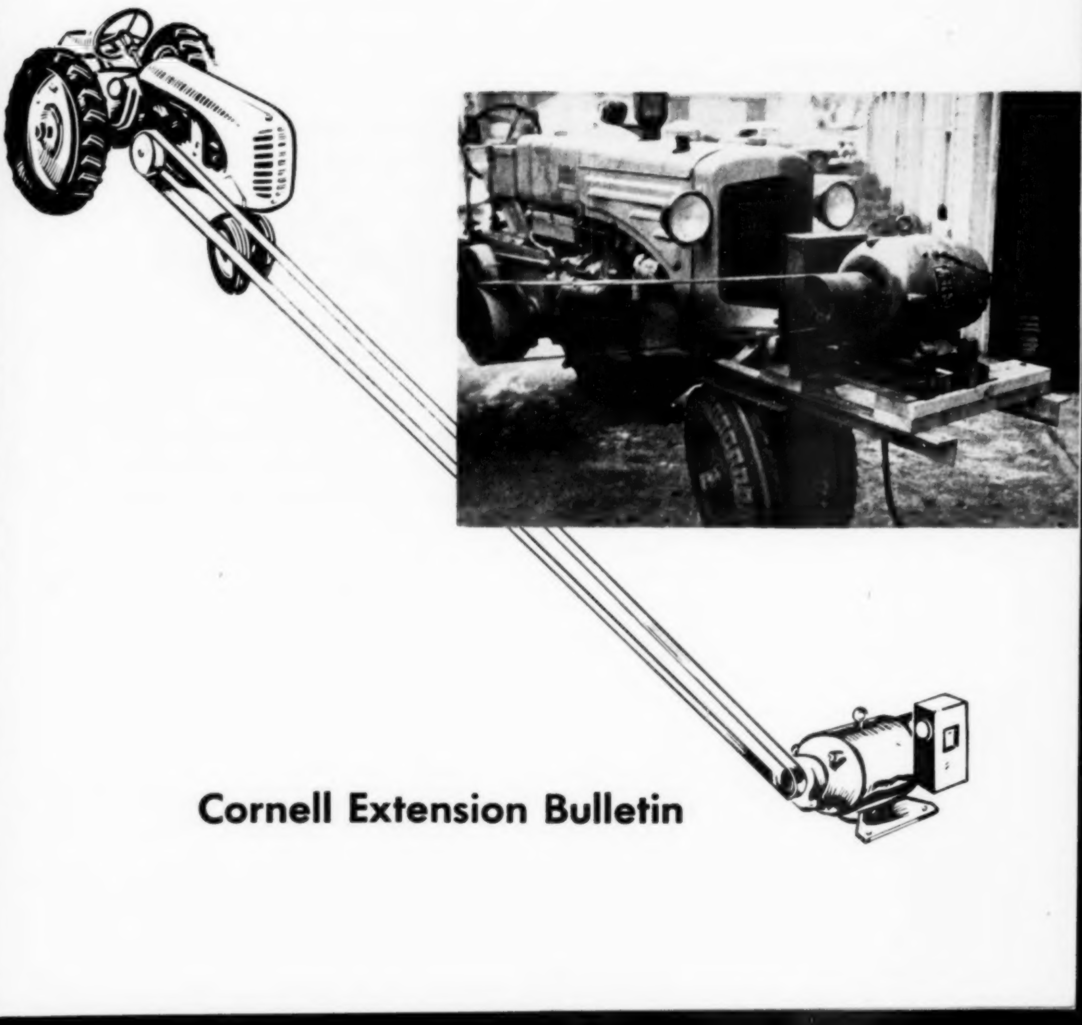
BULLETIN 879

EMERGENCY EQUIPMENT for Electric Power Failures

C. N. TURNER



Cornell Extension Bulletin

Foreword

To make the best selection and installation of an emergency electric generator consult:

1. The farm service representative from your power supplier.
2. The electrical equipment dealer and wiring contractor.
3. The agricultural engineer from the Extension Service.

Electricity is often a mystery. You will have a better understanding of this bulletin after you read the following definitions of some electrical terms:

Ampere. A unit used to express the rate of flow of electricity. It can be compared to gallons per minute flow in a water system.

Volt. The unit of electrical pressure. It can be compared to pressure in a water system.

Watt. A unit of power. The effective volts multiplied by amperes equal watts. With 100 per cent efficiency, it takes 746 watts to equal 1 horsepower.

Kilowatt. A larger unit of power that is equal to 1000 watts.

Current. The flow of electricity along a conductor; its unit is the ampere.

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EMERGENCY EQUIPMENT
For Electric Power Failures

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ELECTRICITY is becoming increasingly important on New York State farms and is available to everyone. It has been accepted as the most convenient and, in many cases, the most economical energy for light, heat, and power on the modern farmstead, and most farms have it. Electricity lowers the cost of production by increasing the output of each farm worker, preserves and often improves the quality of farm products, and lessens much of the drudgery of farm tasks.

The list of appliances and equipment powered by electricity is long and varied. A few of them are: water pumps, milking machines, milk coolers, ventilating fans, stable cleaners, water pipe heating cables, automatic feeders, and many others. In the house, electricity has also become indispensable. Hot and cold running water, lights, electric ranges, refrigerators, freezers, furnace motors and blowers, and even the radio are some of the electrically powered conveniences upon which we are dependent. Electricity has become vital to modern living, but, like the proverbial well, it is not missed until it fails.

Power failures are few and unusual but they are unpredictable and unavoidable. The power suppliers are giving better service each year, but at the same time more equipment has been installed and farm people are more dependent on electric power than ever before.

It is not practical to build electric power lines and other equipment that will withstand all the fury of the elements. When nature goes on a rampage, wind, ice, trees, and floods can damage power lines and upset the entire schedule of modern farm operations. In the event of another war, destructive forces might be unleashed. The power-generating and transmitting stations might become a target for sabotage or bombing.

An electric stand-by generator insures against an interruption in the operation of essential farm equipment during any emergency. Fire insurance on buildings and other property and automobile insurance are common. Insurance against power failures can prevent loss in animal production, damaged water pipes, spoiled food, and hours of hard labor. Often such

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losses cannot be adequately compensated by cash but can be prevented when electric equipment is operated by a tractor or by some other engine-driven generator.

Electric generators mounted on a tractor can furnish power for welders and flood lights to make emergency repairs on machinery in a field away from the regular power lines. These generators can also supply power for electric motor-driven chain saws for use in the farm woodlot and for tree-boring machines in the sugar bush.

While the tractor or gasoline engine-driven generator serves as an ideal substitute for high-line power, the cost for each kilowatt hour generated is from three to ten times that for central-station power, and, therefore, should be considered only for emergency service.

What to Do When the Power Fails

Whenever power fails, follow these steps:

1. Test all fuses and wiring connections to make sure the power failure is not in the farmstead wiring system.

2. Call the power supplier, for the company does not always know that the power has failed. The company strives to give immediate service whenever possible. When, however, a high wind or ice storm blankets an area, the power men may have so many breaks to repair and often under adverse circumstances that they cannot restore service quickly.

3. Turn off all electrical equipment. This is especially important for all motors. A low-voltage condition may exist for a short time when the power is resumed. This low-voltage condition may not provide enough power to enable the motors to run at full speed and thus they may "burn out." Motors left "on" cause a heavy load on the lines when the power is restored. It takes more current to start a motor than it does to operate one at full speed. If all motors attempt to start at the same time, the abnormally high current load may delay the restoration of normal service.

4. Drain water pipes if it is freezing weather. When the pump stops and water is not circulating in the pipes, the water may soon freeze. Water systems that have been protected with electric heating cables may be especially vulnerable.

Some substitutes for electric power are the following:

1. Use kerosene or gasoline lamps and lanterns for light.

2. Do chores by hand.

3. Use belt power from the tractor to run the milking machine and water pumps.

4. Use small-engine belt power, such as a lawn mower, but be sure the engine has twice the horsepower of the motor it replaces.

5. Use the vacuum from the manifold of a tractor, truck, or car to operate your milker units.

6. Use an engine-driven electric generator connected to the farmstead wiring system.

7. Use a tractor-driven electric generator to operate the essential equipment.

The engine- or tractor-driven generator is the most logical choice from the above list. With this type of emergency power, all equipment powered by electricity operates with the regular controls. Milking machine, jet water pump, pressure switches on all water systems, thermostat on the cooler, furnace, brooder, and other electrical appliances can operate properly. The size of the generator, of course, limits the equipment that can operate at the same time. The engine- or tractor-driven generator should be so connected to your electrical system that it prevents feed back into the power company's system. This is accomplished by the use of a double-throw non-selector type of switch and separate wiring to your generator.

The basic information needed in the selection and installation of the engine-driven generator units and the tractor-dirven generators follows:

Selection and Installation of Generator

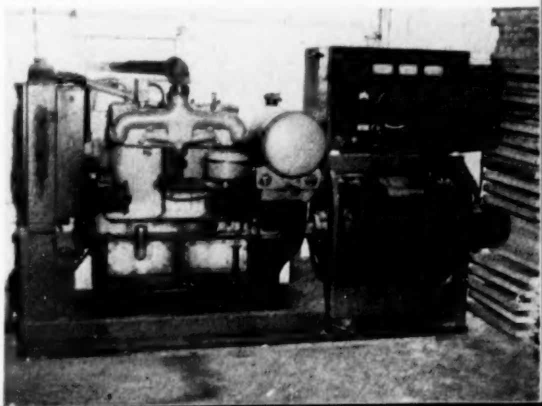
Kind of Units

Engine-driven

The completely automatic engine-driven generator units that can be substituted for central-station power are so installed that they *start automatically* as soon as the high-line power fails and continue to operate until the company power is resumed. This is the type often found in hospitals and other places where a continuous, uninterrupted supply of electrical power is essential. Such a unit would be a luxury on most New York State farms.

The same type of generating unit may, however, be installed with *manually controlled starting,* which makes it possible to use a smaller unit because the operation of equipment can be regulated so the power demand will not exceed the supply (capacity of the generator). You should turn off all electrical appliances and motors that are not essential and stagger the starting load from the other equipment to keep the amount of current to a minimum. This type of generating unit (figure 1) is at present in operation on several New York State farms. It is especially helpful to poultrymen who hatch and brood chicks that need a continuous supply of electrical energy. The use of a power

Figure 1. A gasoline-engine-driven generator for power on a poultry farm should high-line power fail. These complete plants are more expensive than tractor-driven generators of equal size. The engine needs considerable care to keep in operating condition and to assure easy starting when needed.



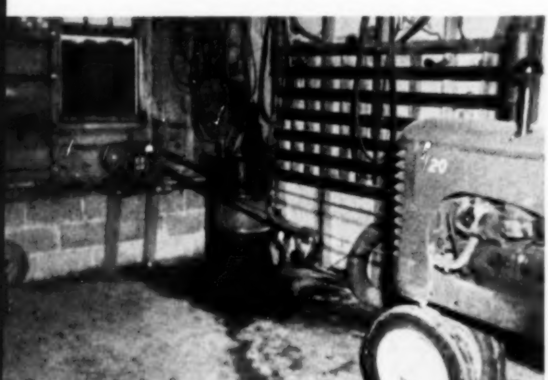
"off" alarm is recommended and manual starting is satisfactory. The size of generator to select and the installation are discussed on pages 6 to 15.

With a unit of this type operated by a gasoline- or diesel-engine, the engine must be kept in starting condition at all times. The engine should be started and allowed to run a few minutes at least once every two weeks to insure its readiness to go into operation when needed. Make sure also that the engine has enough fuel and lubrication and is ready to run at all times. Protect the generator against rodents, for they might build nests inside the frame.

Tractor-driven

Nearly every farm has at least one tractor. On many farms the tractor is kept in year-round operating condition and is used each day. It is, in many instances, the answer to the problem of dependable mechanical power to operate an electric stand-by generator. Consider the horsepower developed by the tractor in choosing a generator. The tractor must develop a minimum of 2 *horsepower* for *each kilowatt* of electric power developed by the generator selected. Most tractors have ample power to operate a generator large enough to meet the critical needs on most farms (figures 2 and 3).

Figure 2. A tractor-driven generator mounted on a permanent base. The double-throw switch is on the outdoor meter pole. Separate wires are run from the generator to the double-throw switch.



Selection of Generator

Generators are available that provide the same type of power at the same voltage as that supplied by the power lines. This is usually 115/230-volt, single phase, 60-cycle alternating current (A.C.). Farms that are not wired for 230-volt service (only two lead-in wires) can use a generator that produces only 115 volts. The generators that produce both 115 and 230 volts are recommended, however, because they will not become obsolete if and when the wiring is changed to a 115/230-volt system.

The first step in selecting the proper size of generator is to determine the essential electrical equipment that must be operated at the same time. Compare this list of critical items with motor types and sizes to determine the power that they will require to start and to operate the motor. The amperes required to run a motor are given on the nameplate attached to the motor, but the starting amperage will be from two to seven times this amount. Likewise, the power required

(watts) to start a motor will also be higher than that required for running (table 1).

It may be possible to stagger the load so the milk cooler can be turned off while the milking-machine motor is running. For example, all equipment can be turned off while the stable cleaner is operating. Each farmer must determine the list of critical items

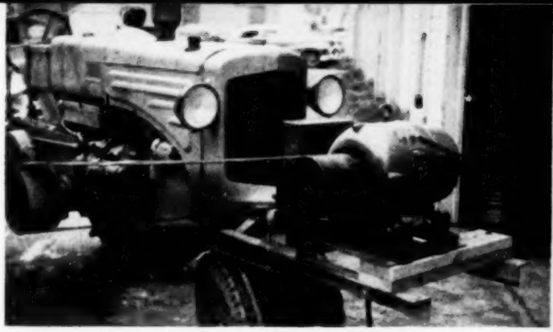


Figure 3. A generator mounted on a tractor. This portable generator can be used at house, farm, farm shop, and poultry house to power essential equipment or in the field or farm woodlot. A short cable connects the generator to the "double throw" switch for an individual circuit or a combination of circuits.

Table 1. Starting and running requirements for a few 60-cycle, single-phase, induction motors on farm equipment

Motor horsepower	Starting			Running at full load		
	115 volts	230 volts	Either voltage	115 volts	230 volts	Either Voltage
Split Phase	*Amperes*	*Amperes*	*Watts*	*Amperes*	*Amperes*	*Watts*
1/6	15 to 30		860	4	*	215
¼	20 to 35		1,500	5	*	300
1/3	25 to 40	10 to 18	2,000	5.2†	2.6	400
Capacitor						
¼	15 to 20		1,200	4†	*	300
1/3	20 to 30	10 to 18	1,600	5	2.5	400
½		12 to 20	2,300	§	3.5	575
¾		15 to 25	3,345		5	835
1		18 to 30	4,000		6	1,000
1½		27 to 40	6,000		9	1,500
2		45 to 55	8,000		12	2,000
3		65 to 75	12,000		17	3,000
5		95 to 110	18,000		28	4,500
Repulsion Induction						
¼	10		900	4	*	300
1/3	12		1,200	5†	2.5	400
½		7 to 10	1,725	§	3.5	575
¾		12 to 16	2,500		5	835
1		18 to 25	3,000		6	1,000
1½		25 to 30	4,500		9	1,500
2		30 to 40	6,000		12	2,000
3		50 to 60	9,000		17	3,000
5		90 to 100	13,500		28	4,500
7½		120 to 130	21,000		40	7,000

*Motors this size are usually built for 115 volts.
†Motors connected to 115 volts require twice the amperage as those connected to 230 volts.
§All motors ½ horsepower or larger should be connected to 230 volts for best operation.

and calculate the watts required for each (table 1). Two small motors can often be operated simultaneously if they are *not started* at the same time. Start the larger or more heavily loaded one first. Electric lights, unless many are used, need not be figured if they are turned on *after* the motors are started.

Balancing the Load

Maximum generator efficiency is obtained when both coils or sides of a 115/230-volt generator have an equal load. Such a generator is essentially two 115-volt units in one machine. For example, a 115/230-volt generator rated at 3000 watts develops this at 230 volts or develops 1500 watts on each coil at 115 volts. The 230-volt equipment draws power from both sides of the generator and does not have to be considered in balancing the load. The 115-volt circuits, however, should be checked and divided so that part of the load is on each coil and one of them is not overloaded. This applies to lights and to smaller motors that are connected to the 115-volt service. If these were all hooked on one coil, your generator would have only half its rated capacity because one coil would be doing all the work. The electrician should provide a balanced load when he hooks up your generator.

Three Types of Motors

Three standard types of motors are in common use on New York farms. You must know the type of motor before you can estimate the starting current in amperes (table 1). This starting amperage in turn gives you an indication of the power needed in terms of watts or kilowatts.

Split-phase motors are generally used on washing machines and small workshop tools with low starting requirements. They are usually found in sizes of 1/3 horsepower or less. A ¼-horsepower, split-phase motor connected to a 115-volt line requires about 5 amperes while running and delivering its full rated load. For a second or two while starting and coming up to full speed, it draws from 25 to 35 amperes, depending upon the motor, the load, and the wiring. This is from five to seven times greater than its running requirements. Restrict the use of split-phase motors whenever possible, but they can be used with the proper size of generating unit.

Capacitor motors are in common use on many farms and can usually be identified by a condenser in a cylindrical type of box on top of the motor and by the absence of brushes. Capacitor motors are made in sizes up to 5 and sometimes 7½ horsepower. A ¼-horsepower motor of this type operates at approximately 4 amperes under full load and requires a starting current of from 15 to 20 amperes or from four to five times its running amperage.

Repulsion-induction motors have brushes and are generally used on machines that start with a heavy load, such as water pump, furnace stoker, milk cooler, stable cleaner, or milking machine. The running current of a ¼-horsepower repulsion-induction motor at full load is about 4 amperes, but

the starting current is only from 10 to 12 amperes. This is from two to three times the running requirements (table 1). Stable cleaners and deep-well pumps that start under an unusually heavy load have a higher starting amperage than indicated in table 1.

Motor Protection

Protect *all* motors with thermally operated switches or time-delay fuses that break the circuit if the motor draws too much current. The standard fuse in a motor circuit needs to be so large to carry the high starting current that it provides no protection for the motor while running. This same type of protection should also be built into the generator. Refer to Cornell Extension Bullein 673, *Protection for Electric Motors*, by E. S. Shepardson.

How to Calculate Generator Size

Select a generator that develops enough power to start and run the equipment that has been classified as critical.

Generators are rated by the manufacturer in terms of watts or kilowatts. It is possible to get an approximate figure as to the number of amperes they draw by dividing watts by volts. For example, a 115/230-volt generator of 3000 watt capacity will carry $\frac{3000 \text{ watts}}{230 \text{ volts}} = 13$ amperes at 230 volts. This rating in amperes is also given on the generator name plate and will help you compare the total full-load ampere rating of your motors with that of the generator.

Because generators are rated and sold on the basis of power (watts or kilowatts) developed, approximate wattage requirements for motors have been included in table 1. This table shows the power requirements of standard-size motors when operating at full load. Watts are considered in the calculations of generator size so the result will correspond to the manufacturer's output ratings.

The difference in motors is given to determine the power requirements on the basis of their type and size. If split-phase motors are *not* used, it can be assumed that the starting wattage required by the motor will be from three to four times the running wattage as shown in table 1.

The overload capacity of a generator to start a motor varies, but it is assumed that for starting purposes a generator produces 25 per cent above its rated capacity. Follow the manufacturer's specifications to determine not only the normal power rating of the generator but also its overload capacity needed to start a motor. The following examples may be used as a guide in determining the generator needed for a particular operation:

Example 1

A farmer has a $\frac{1}{4}$-horsepower motor on the water pump and a $\frac{1}{2}$-horsepower motor on the milking machine. Both of these are critical items and may have to be run but not started at the same time. Some electric lights will also be needed. The starting wattage will be from three to four times the running wattage (table 1).

	Approximate Starting Watts	*Full Load Running Watts*
½-horsepower motor (R I)	1725	575
¼-horsepower motor (Capacitor)	1200	300

Start the largest motor first, which requires 1725 watts but then drops back to 575 watts as it reaches normal operating speed. Then start the smaller motor, which requires 1200 watts. The generator will be called upon to deliver 1775 watts. (The running wattage of the first motor plus the starting wattage of the second.) A 2000-watt generator should start and run these motors and also furnish power for lights after the motors have been started. This does not allow for equipment that might be purchased later, thus a 3000-watt generator should be the smallest size to consider. The additional cost will be small.

Example 2

	Approximate Starting Watts	*Full Load Running Watts*
1-horsepower milker motor (R I)	3000	1000
½-horsepower cooler motor (Capacitor)	2300	575
¼-horsepower water pump motor (R I)	900	300

If all three motors were started at the same time, it would require at least a 6000-watt (6 k.w.) generator. However, the load may be staggered so by starting the largest motor first a minimum of 3000-watts (3 k.w.) would be required. This is the power required to start the largest motor. With all motors running, only 1875 watts would be required and this would leave additional power for electric lights. A 3000-watt generator should operate the above equipment.

Example 3

	Approximate Starting Watts	*Full Load Running Watts*
2-horsepower stable cleaner motor (R I)	6000	2000
1-horsepower deep well pump (R I)	3000	1000
½-horsepower milk cooler (Capacitor)	2300	575

In this case it will be necessary to have a generator with a starting capacity of 6000 watts. Some manufacturers market 5000-watt generators that have a starting capacity of 6000 watts, but no reserve capacity would then be available

From these examples it can be seen that a 3000-, 5000-, or 6000-watt generator will produce enough power for many farms. Generators of larger capacity are available for motors larger than 2 horsepower and for a number of critical items that must be run together and require more than 3000 watts running load. Usually, they are rated at 5 kw, 6½ kw, 10 kw, 12 kw, and larger. The size of generator to select depends upon the largest motor to be started and the critical items that must be operated at one time. As a guide, allow 2 kilowatts for each horsepower of the motor to be operated.

Installation of Generator

After a generator of a proper size has been selected to meet the emergency requirements, the next thing to decide is where to install the unit. A frame may be built and mounted on

the tractor for a portable unit (figure 3). The following points should be considered when planning the location of the generator:

1. Protection from the weather so the belt from the tractor will not slip during a rain storm.

2. Near the main service entrance from the power line. This requires a minimum run of wire to the generator.

3. Whether it is to be used on all circuits or only those that supply the essential equipment.

The generator should either be mounted on the tractor or bolted to a permanent concrete base. A location should be selected where the tractor can be easily lined up to furnish the mechanical energy to run the generator.

The size of electric wire needed for the generator installation depends upon the amount of current and the distance the current must be carried. Wire sizes are discussed in Cornell Extension Bulletin 849, *Adequate Farm Wiring Systems.* The expense of extra long runs of wire often makes it desirable to locate the generator near the switch to which it will be connected.

Connecting to the circuit

Use a 3-pole solid neutral, two-blade, double-throw switch to transfer the load from the power line to the generator (figure 4). Some authorities may require the use of a 3-blade

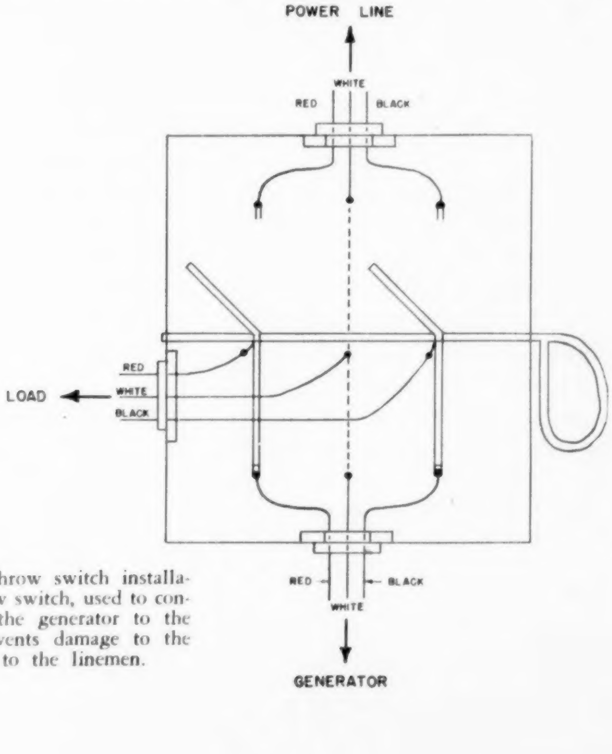


Figure 4. A double-throw switch installation. The double-throw switch, used to connect and disconnect the generator to the electrical system, prevents damage to the generator and injury to the linemen.

double-throw switch that disconnects the neutral or ground wire.

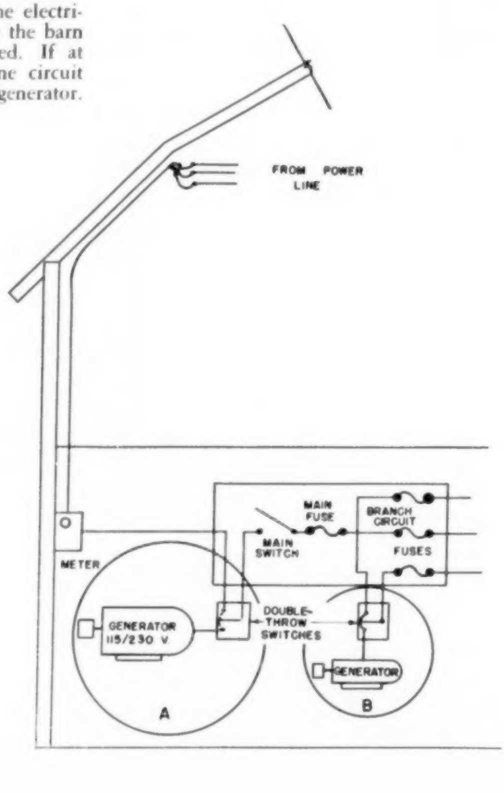
This "double-throw" switch serves two purposes:

1. It protects the servicemen making repairs on the power line from being injured by current passing from the generator to the high line. As the power produced by the generator passes through a transformer, it is stepped up to a dangerously high voltage.

2. It prevents the generator from being damaged. If the generator was connected to the power line by mistake and the power-line service is restored, it may burn out the generator.

This switch must be large enough to carry all of the current that is in the service-entrance wires to the farmstead or to the building (figures 5 and 6). This varies with the installation, but the "double-throw" switch must have a rating in amperes equal to that

Figure 5. A double-throw switch installed at several different locations in the electrical system. If installed at *A* both the barn and other buildings will be served. If at *B*, only the equipment on the one circuit in the barn will be served by the generator.



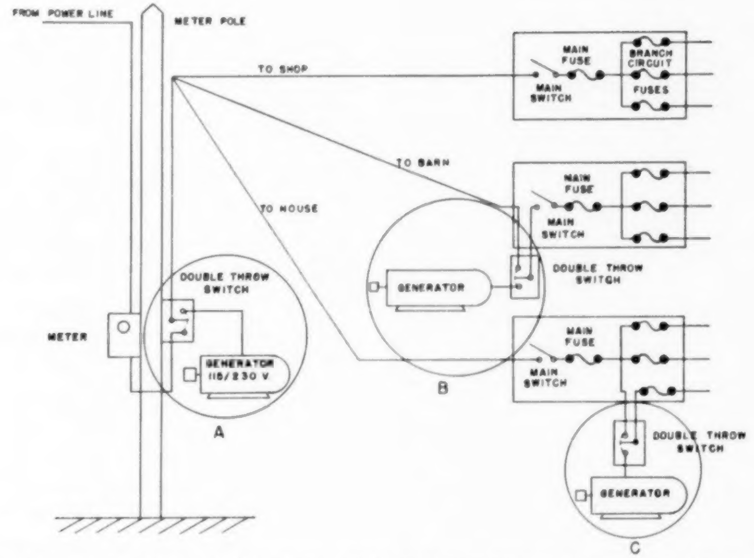


Figure 6. The two-blade, double-throw switch and generator at *A*, *B*, or *C*. At *A*, the entire wiring system will be energized; at *B*, only the barn wiring system; and at *C*, only the one-branch circuit at the house will have emegency power. The size of the double-throw switch must be equal to the ampere capacity of the wire that supplies the power from the high line. The generator can be at any convenient place, provided the cable to the double-throw switch is large enough to carry the load.

of the main switch, the service entrance wires down the meter pole, or the service entrance conductors entering the building. If installed for a circuit in the building, it needs to be only large enough to carry the rated ampere capacity of that particular circuit and must be installed ahead of the fuse in that circuit.

Because of the expense involved in purchasing this large switch, it may be advisable in some instances to install the generator so only one of the circuits or a part of a circuit supplies the critical equipment. This allows you to use a "double-throw" switch of a smaller size (figure 6,C). This is satisfactory only if the one or more critical items are all operated from this same circuit.

It is possible that the wiring system may correspond to that shown in figure 6. If so, you may locate the "double-throw" switch at one of three general locations as shown:

Point A: On the meter pole where the electricity comes from the power line and goes through the meter box. Installed here the electrical equipment will operate as usual within the output limit of the generator. The "double-throw" switch in this case must have a rating equal to the ampere capacity of the service conductors installed down the meter pole. This is the capacity of the wiring system and be-

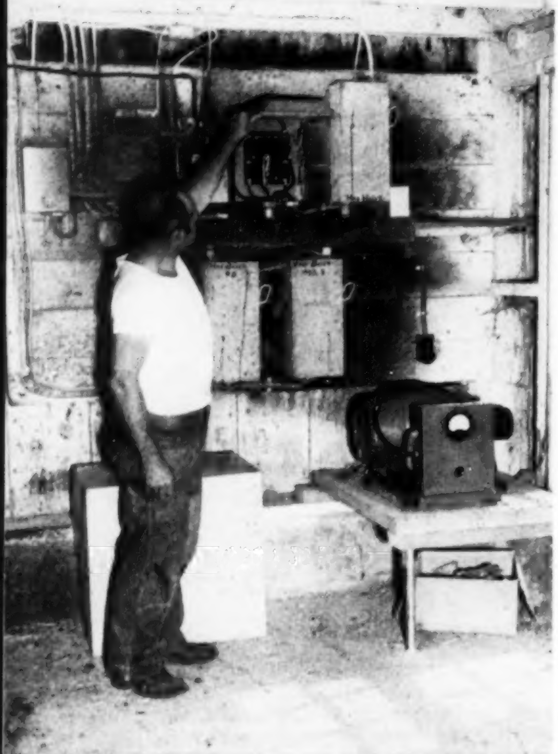


Figure 7. A double-throw switch in the barn (above) or on the meter pole (below). A double-throw switch is the key to safety in an emergency generator-insurance program.

cause all the current from the high line is carried by the double-throw switch in this location, the switch must be large enough to handle this current.

Point B: At the main service in any one of the buildings. The size of the switch needed will be smaller than in location B but power will be supplied only to the building it serves. In this instance the ampere rating of the switch must equal that of the main switch or the service entrance conductors (figure 5).

Point C: In any one of the branch circuits to run critical items on only that circuit. This is satisfactory only when all the critical equipment is on one branch circuit.

Protection of Generator

Protect the generator to insure satisfactory operation:

1. Protect against excessive current from the power line by a "double-throw" switch.

2. Protect against overload by a thermal cut-out switch or a time-delay fuse built into the generator control box. (See manufacturer's description of unit.)

3. Protect from weather.

4. Protect the electrical equipment with a fuse against damage due to a short circuit in the line if the emer-

gency power does not pass through the regular fuse box.

5. Protect from mice nests when idle. A $\frac{1}{4}$-inch mesh screen over ventilating openings is desirable.

6. Protect bearings by lubrication but do not oil the brushes.

7. Protect against lightning damage or line-feed back by grounding the frame of the generator.

8. Protect against accidents by using a belt guard.

Proper Pulley Size

When you order the generator from the dealer, be sure to specify the correct pulley size. A simple calculation determines the proper pulley for your generator. You need the following information:

1. Tractor-belt pulley speed at full governed throttle (revolutions per minute of belt pulley).

2. Generator speed in rpm (manufacturer's specification on name plate).

3. Diameter in inches of tractor pulley. You should substitute this information in the following equation:

pulley diameter (*inches*) on generator $= \frac{\text{tractor pulley speed}}{\text{generator speed}} \times$ tractor pulley diameter (*inches*)

For example:

Tractor speed = 1200 rpm
Generator speed = 1800 rpm
Tractor pulley = 10 inches

generator pulley diameter (inches) $= \frac{1200}{1800} \times 10 = 6.66$ inches

Under these conditions order a $6\frac{1}{2}$-inch pulley for the generator.

Protection against Exhaust Fumes and Fire

Any gasoline engine that runs indoors must have an exhaust leading outside to prevent the accumulation of poisonous gases. If you use a tractor to operate the generator and it is in a building, use flexible tubing or stove pipe to carry the exhaust gases outside.

An open door or window is not enough protection because the wind might prevent the escape of the poisonous gas. No precautions against fumes need to be taken if the tractor will be running outside; but regardless of where the tractor will be placed, take precautions to prevent fires from starting by flying sparks from the exhaust.

Starting the Generator

If everything is in order, put the belt on the tractor and generator pulleys. Start the tractor and advance the throttle so the voltmeter on the generator registers 250 volts for 115/230 units or 125 volts for 115-volt units. It will drop when the load is turned on.

Turn on the essential motors one at a time, the largest motor first. After the motors have been started, turn on the fewest electric lights needed.

Check the voltmeter on the generator. If it has fallen below the normal operating voltage (115 or 230), either speed up the tractor or turn off some of the electrical equipment. Listen to the electric motors and make sure they sound as though they are running at normal speed.

In Brief

The following points should be considered in preparation of any emergency:

1. Determine the critical equipment on the farm and the amount of power it needs to start.

2. Install a "double-throw" switch of a size to handle the maximum current that will flow through the circuit when connected to the power line.

3. Install a generator that meets the following requirements:

   Has a thermal overload device to protect against burn out.

   Has a rating in kilowatts that is large enough to handle the critical items that must be used simultaneously. (Many farms require at least a 5000-watt generator.)

   Has a belt pulley of proper size to operate with the available tractor at full governed speed.

4. Make arrangements to carry off exhaust fumes and to protect against the danger of fire.

Dividends can now be drawn from the generator that was purchased as insurance against power failures. This pays off better than most farm insurance because it assures that the "electric hired men" will continue to work regardless of weather conditions or other destructive forces.

The farm service representative of the electric company or power supplier, the electrical equipment dealer or the district extension agricultural engineer will be glad to assist in any problem that might be encountered in selecting and installing a stand-by generator.

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